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STRATUS CLOUD NEAR THE EAST COAST OF GREAT BRITAIN

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STRATUS CLOUD
NEAR THE EAST COAST OF GREAT BRITAIN

By G. A. Bull, B.Sc.

This paper was written in 1938

When the wind blows from the North Sea, the sky over the east coast of Great Britain is frequently covered with a low layer of stratus or stratocumulus cloud, even though pressure is high and conditions are anticyclonic. The cloud belongs to the type which produces what W. H. Dines so aptly called " anticyclonic gloom ". Among forecasters it is known as North-Sea cloud.

Changes from the state of " gloom " to one of brilliant sunshine and *vice versa*, occur with remarkable rapidity in these conditions. A broken layer of this cloud is, in fact, uncommon except for a short time whilst it is breaking up or clearing.

Much of the cloud that occurs with easterly winds is, of course, produced by fronts but only non-frontal cloud is considered in this paper.

Physics of the cloud.—The cloud is produced by dynamical turbulence, which lifts the air near the earth's surface sufficiently to cause condensation of the water vapour contained in it. The physical conditions for the existence of turbulence cloud are given, briefly, in the following.

The height to which turbulence extends must be at least equal to the height through which the surface air must be raised for it to become saturated with water vapour. This height is called its " saturation height ".

The saturation height of the surface air may be found, using a tephigram or other pressure-temperature diagram, by drawing the dry-adiabatic curve through the point representative of the surface pressure and dry-bulb temperature, and the saturation-adiabatic curve through the point representative of the surface pressure and wet-bulb temperature. The point where these two curves intersect, if they do intersect, gives the pressure and temperature of the level to which the surface air must be raised for it to become saturated. The curve of constant water-vapour content through the point representative of surface pressure and dew point passes through the point of intersection of the dry-adiabatic and saturated-adiabatic curves previously mentioned, and so may be used instead of the saturated adiabatic through the wet-bulb point. Since absolute humidity in general decreases with height, the surface air becomes mixed with drier air above so that the cloud base is generally rather higher than the value calculated in this way. The difference is however usually quite small. Suppose now there is a sheet of stratus cloud maintained by turbulent convection, and that the pressure and temperature at its upper surface are known. Then if the temperature of the surface air is raised, without increasing its water-vapour content, to a value such that its saturation level lies at, or above, the cloud top then the cloud would be expected to disperse. This value is found from the temperature-pressure curve by drawing the dry-adiabatic curve from the point representative of the pressure and temperature at the cloud top to intersect the curve of surface pressure. The point of intersection gives the required temperature. For fuller details Poulter[1]*, Brunt[2] and Krick[3] should be consulted.

* The index numbers refer to the bibliography on p. 16.

The height of the turbulent layer depends upon the lapse rate of temperature, wind speed, and the roughness of the surface over which the air flows. According to Rossby[4], for winds up to force 4 the height of the layer of frictional influence is, roughly, directly proportional to the wind speed at anemometer heights, and over open country is 1,000 ft. for a wind of 10 m.p.h. For winds above force 4 this height is less than the figure obtained from this formula. Further, above the turbulent layer there must be a region of lapse rate less than the saturated-adiabatic value so that thermal convection does not take place. Generally, an inversion is found above the cloud, produced by anticyclonic subsidence, but this is not essential. Cases have been noted in which the lapse rate above the cloud was between the saturated adiabatic and isothermal lapse rates.

Once the cloud has been formed the following effects tend to destroy it :—

(*a*) Increase of temperature at the ground without compensating increase in absolute humidity, causing the cloud base to rise ;

(*b*) Increase of wind speed leading to increased turbulence so that the cloud mixes with the drier air above ;

(*c*) Absorption of solar radiation by the top of the cloud ;

(*d*) Subsidence of the whole layer due to changes in the pressure distribution or possibly to sea-breeze effects, causing dynamical heating of the subsiding air and consequent evaporation of the cloud.

Supposing that no changes in pressure distribution take place, then over land, as is well known, the first effect is much the most important. Over the sea there is, according to all available information, a diurnal change in surface air temperatures of only about 2°F If this is the only factor of importance, there should be little diurnal variation in the amount of turbulence cloud over the sea.

Such information as is available on absorption of solar radiation by clouds suggests that it is small. Hewson[5] shows that if the zenith distance of the sun is 25°, a cloud sheet 200 m. (660 ft.) thick containing 1 gm. liquid water per cubic metre in drops of radius 2×10^{-3} cm. absorbs about 5 per cent. of the incident radiation, of which about 1·9 per cent. is absorbed by the uppermost 50 m. (165 ft.).

A layer of low stratus sometimes forms over the coast with off-sea winds and clear sky over the sea. This is due to horizontal convergence and consequent ascending motion caused by the greater friction over the land than over the sea. W. Peppler[6] suggests that the elevation of the air is probably only a few yards in this case. This type of coastal stratus forms only with very damp air and winds so light that the turbulence over the sea is insufficient to lift the lower air to saturation level. In the early morning this cloud may spread some distance inland, but, if there is no higher cloud to check insolation, it rarely survives the early morning hours. On most occasions when observed it is merely a line of stratus over the coastline.

Diurnal variation.—A statistical analysis of the diurnal variation in the amount of North-Sea cloud at Felixstowe for the period 1931-38 is given in Tables I to IV. Occasions when the wind was off sea but there was no cloud are included, but days when the off-sea wind was merely a sea breeze have been, as far as possible, excluded.

Table I gives the percentage frequency of occasions when the cloud amount was 7 tenths or more, 3 tenths to 6 tenths, and 2 tenths or less, for 0700, 1000, 1300, 1600, and 1800 G.M.T. Separate tables are given for the winter (November

TABLE I—PERCENTAGE FREQUENCY OF CLOUD AMOUNT AT STATED HOURS

Period 1931-38

Time	Cloud amount tenths 7—10	3—6	0—2	No. of occasions
G.M.T.				
		Winter months		
0700	74	15	12	159
1000	72	17	11	159
1300	72	12	17	159
1600	71	14	15	157
1800	68	12	20	159
		Equinoctial months		
0700	47	15	38	162
1000	41	15	44	162
1300	30	22	48	162
1600	26	17	56	162
1800	33	13	56	162
		Summer months		
0700	35	22	45	169
1000	32	16	52	169
1300	19	17	63	169
1600	19	13	69	169
1800	19	15	66	169

TABLE II—PERCENTAGE FREQUENCIES OF CLOUD AMOUNT ON DAYS WHEN CLOUD AMOUNT AT 0700 G.M.T. WAS 7 TENTHS OR MORE

Period 1931-38

Time	Cloud amount tenths 7—10	3—6	0—2	No. of occasions
G.M.T.				
		Winter months		
0700	100	..	..	117
1000	90	9	0	117
1300	83	11	5	117
1600	80	11	8	117
1800	74	12	13	117
		Equinoctial months		
0700	100	..	..	75
1000	79	16	5	75
1300	55	20	26	75
1600	42	22	35	75
1800	50	18	33	75
		Summer months		
0700	100	..	..	59
1000	62	19	18	59
1300	45	20	35	59
1600	42	14	46	59
1800	42	20	38	59

TABLE III—PERCENTAGE FREQUENCIES OF CLOUD AMOUNT ON DAYS WHEN CLOUD AT 0700 G.M.T. WAS 3 TENTHS OR 6 TENTHS OR BETWEEN

Period 1931-38

Time	Cloud amount tenths 7—10	3—6	0—2	No. of occasions
G.M.T.				
		Winter months		
0700	..	100	..	24
1000	25	50	25	24
1300	45	24	31	24
1600	50	24	25	24
1800	53	16	28	24
		Equinoctial months		
0700	..	100	..	25
1000	33	33	33	25
1300	32	36	32	25
1600	32	28	40	25
1800	36	16	48	25
		Summer months		
0700	..	100	..	33
1000	33	39	27	33
1300	12	33	54	33
1600	15	24	61	33
1800	12	27	61	33

TABLE IV—PERCENTAGE FREQUENCIES OF CLOUD AMOUNT ON DAYS WHEN CLOUD AMOUNT AT 0700 G.M.T. WAS 2 TENTHS OR LESS

Period 1931-38

Time	Cloud amount tenths 7—10	3—6	0—2	No. of occasions
G.M.T.				
		Winter months		
0700	..	..	100	18
1000	12	23	67	18
1300	23	6	72	18
1600	39	12	50	18
1800	44	6	50	18
		Equinoctial months		
0700	..	..	100	62
1000	2	6	93	62
1300	0	18	82	62
1600	5	6	89	62
1800	8	7	85	62
		Summer months		
0700	..	..	100	77
1000	7	6	87	77
1300	5	6	88	77
1600	5	5	90	77
1800	2	7	91	77

to February), equinoctial (March, April, September, October) and summer (May to August) months. The table for the winter months shows the predominance of cloudy skies at that season with hardly any variation during the day. During the equinoctial and summer months the tables show that not only is the frequency of cloudy skies much less, but also that there is a marked maximum of cloud amount in the early morning. Tables II, III and IV bring out the diurnal variation more clearly. Table II is for days when the cloud amount at 0700 G.M.T. was 7 tenths or more. It shows that during the winter months if the sky is overcast or nearly so with North-Sea cloud at 0700 G.M.T. there is little hope of it clearing during the day. On the other hand, in the equinoctial months there is roughly an even chance that by midday the sky will be less than half-covered with cloud, and a still greater probability at the later hours. Table III is for days when the cloud amount at 0700 G.M.T. was 3 tenths to 6 tenths. During the winter there is an even chance that by midday the sky will have become overcast, and only about one chance in four that the cloud amount will decrease to 2 tenths or less. In the summer the cloud is likely to decrease and the chance of becoming overcast or nearly so is small. In the equinoctial months the conditions are similar to those of the summer but with rather less chance of the sky clearing. Finally, Table IV refers to days when the cloud amount at 0700 G.M.T. was 2 tenths or less. In the summer and equinoctial months the chance that the cloud amount will not increase is about nine to one. In winter there is almost an even chance that by 1800 G.M.T. the sky will be over 7 tenths covered. A rather striking feature of the tables is the marked tendency for cloud amounts between 3 tenths and 6 tenths to be less frequent than either those over 7 tenths or those below 2 tenths. This tendency for either an overcast or clear sky with off-sea winds is very noticeable on the east coast.

There is very little published information on the diurnal variation of cloud over the sea. Köppen[7] gives summaries of 25 years' observations at the Dutch lightships in the North Sea, Nord Hinder (51° 35′ N., 2° 37′ E.) and Terschellingbank (53° 27′ N., 4° 47′ E.). These show a tendency for the amount of cloud to be least at midday and midnight, and greatest at 2000 and at 0800. The maximum at 0800 is more marked than the other extreme. The data are, apparently, for all types of cloud and all wind directions. Wadsworth[8], describing cloud observations made at Malta in 1924 and 1925, states that stratus was more frequent in the early part of the night than during the day, while stratocumulus had a maximum frequency in the morning and a secondary maximum in the evening.

When the sheet of North-Sea cloud disperses at Felixstowe it clears first over the land. The first sign of clearance is the appearance of " lanes " of blue sky, which divide the cloud into lumps. These rapidly diminish in size and finally disappear. The cloud sheet is then left over the sea with wisps of cloud being carried inland by the wind. Frequently, the cloud is subsequently observed to clear over the sea. Cloud observations made by the pilots of an aircraft flying over the North Sea on the afternoon of May 6, 1938 are noteworthy in this connexion. On this day the wind was NE.—E., force 3 to 4 on the coast of East Anglia. In the morning the sky was overcast with stratus cloud at 2,500 ft. This cloud decreased to 3 tenths or less inland and on the coast of East Anglia by midday. At Felixstowe the sky was clear in the afternoon except for fragments of stratus cloud just visible above the sea horizon. In the course of a flight from Felixstowe over the North Sea in the afternoon, it was observed that the stratocumulus cloud commenced at a distance of 30 miles from the coast. From 30 to 50 miles out there was broken stratocumulus cloud, and beyond 50 miles a continuous sheet of stratocumulus. The relative humidity of the air was 60 per cent., dew point 38°F., and the

condensation level of the surface air deduced from the tephigram, 2,300 ft. The sea temperature in early May is about 48°F. and the air temperature at Felixstowe rose from 46°F. at 0700 G.M.T. to 53°F. in the afternoon. On the Kent coast the cloud persisted all day.

On another day, May 2, 1937, with off-sea winds force 3 to 4, relative humidity 90 per cent. at 0700 G.M.T. and 70 per cent. at 1300 G.M.T., and dew point 43°F., there was 10 tenths cloud at 500 ft. in the early morning which cleared only over the land. The cloud persisted over the sea right up to the coast throughout the day, and spread in over the land again in the evening.

This clearance of the cloud up to some distance off the coast following its clearance over the land has also been noted off the Norfolk coast by Mr. Zobel (then at Bircham Newton). Lamb[9] reports a clearance of sea fog off the east coast of Scotland on certain occasions following the setting-in of the sea breeze. As Lamb points out the sea breeze must be fed by descending currents over the sea. It is probable that this clearance over the sea of North-Sea cloud with a continuous wind from sea to land is due to the increase in wind towards the coast which, owing to sea-breeze effect, takes place when the land is directly heated by the sun. This increase must lead to subsidence of the air over the area where it takes place. The effects of subsidence on cloud sheets are complex and it is not at present possible to provide a quantitative explanation of the cloud clearance in this way. There are three effects to be considered :—

(*a*) Evaporation of the cloud particles by adiabatic heating. This alone is too slow, as a stratus cloud would need to descend about 1,000 ft. to be completely evaporated.

(*b*) Instability at the base of the cloud, due to the air in the cloud heating at the saturated adiabatic lapse rate and the air below at the dry adiabatic lapse rate. As noted on p. 386 of Brunt's treatise[2] this convection tends to maintain the cloud if enough moisture is carried up to overcome the evaporation. On the other hand these convection currents may, in the case of thin stratus clouds, assist the dissipation by causing mixing with the relatively dry air above.

(*c*) The subsidence in the air well below the cloud will reduce the vertical eddy currents and consequently the transport of water vapour upwards from the sea surface. This will tend to cause dissipation of the stratus clouds.

According to Sutcliffe[10] the increase in a general off-sea wind, due to sea-breeze effect, is only 2–3 m.p.h. at most. Assuming that this increase is spread over ten miles the rate of change of vertical velocity with height is about 0·1 ft./sec./1,000 ft. which gives a subsidence of about 300 ft./hr. at a height of 1,000 ft., assuming that the increase in wind does extend up to that height.

In connexion with the distance to seawards over which the sea breeze occurs it is worth noting that Goldie[11] found marked evidence of it on analysing the diurnal variation of wind recorded by the Dines anemometer at Bell Rock, 12 miles off the east coast of Scotland. It would be of interest to know up to what distance seawards the sea-breeze effect is perceptible, especially when there is a general off-sea wind.

When the cloud disappears it leaves a layer of haze, which only clears slowly, and gives poor vertical visibility. This is noted by W. Peppler[6] in his work on stratus formation over Lake Constance. When the cloud returns to the coast it does so in the form of lumps and filaments carried in from over the sea. These gradually grow larger and coalesce. In spring and autumn these fragments reappear as a rule about sunset.

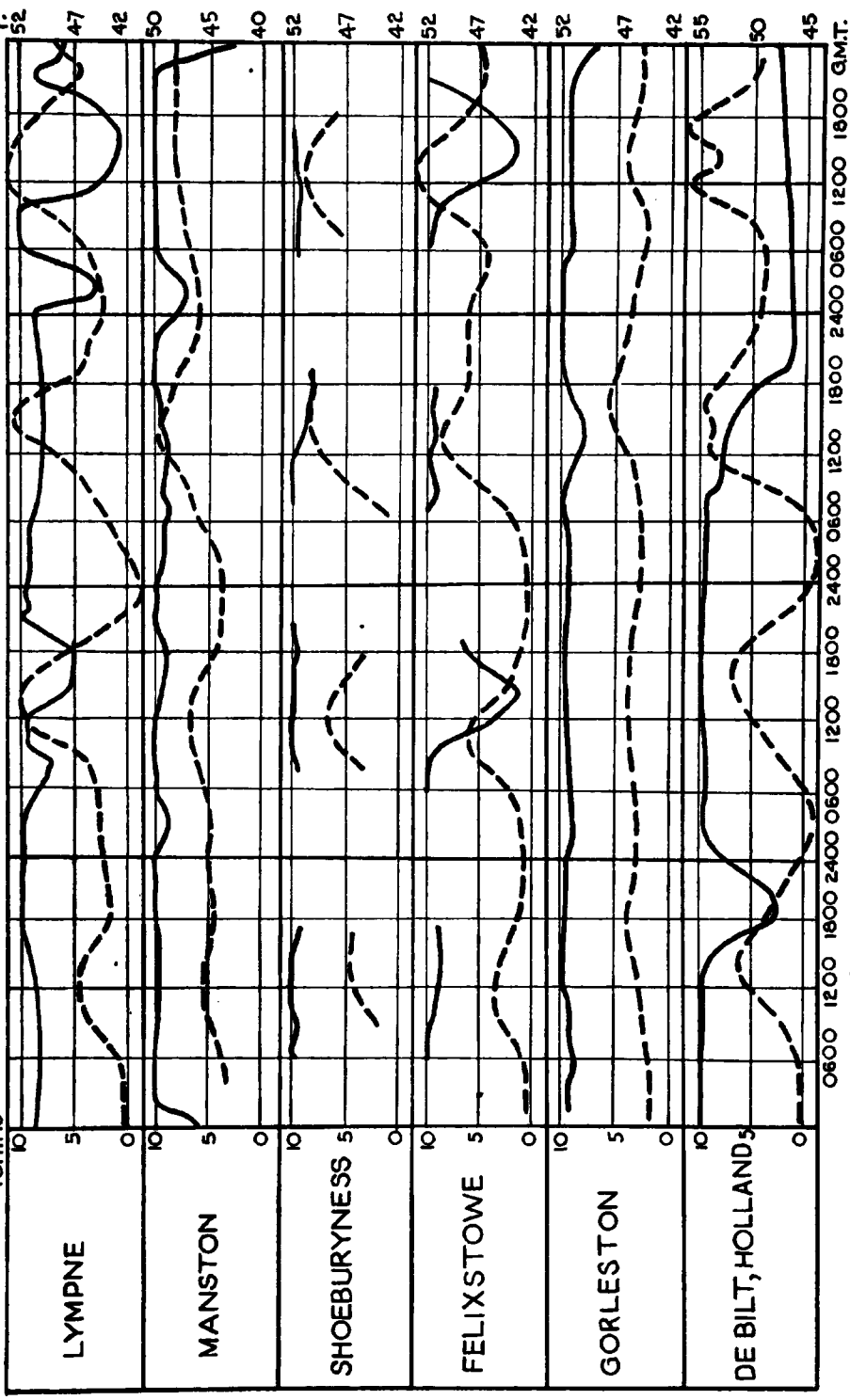

FIG. 1.—CLOUD AMOUNT AND TEMPERATURE WITH NE. WINDS

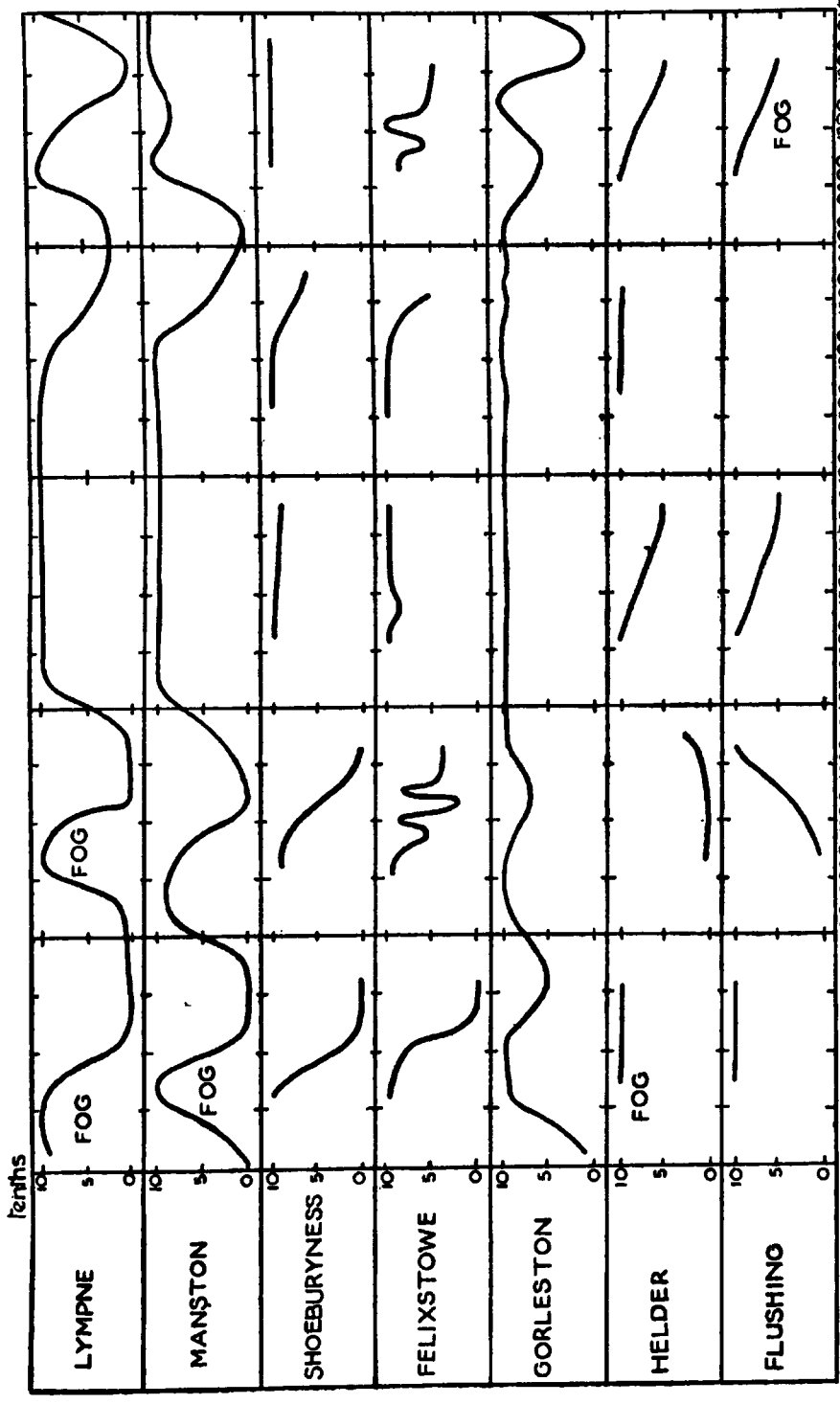

FIG. 2.—CLOUD VARIATION WITH E. WINDS
Cloudiness given in tenths of sky covered with low cloud

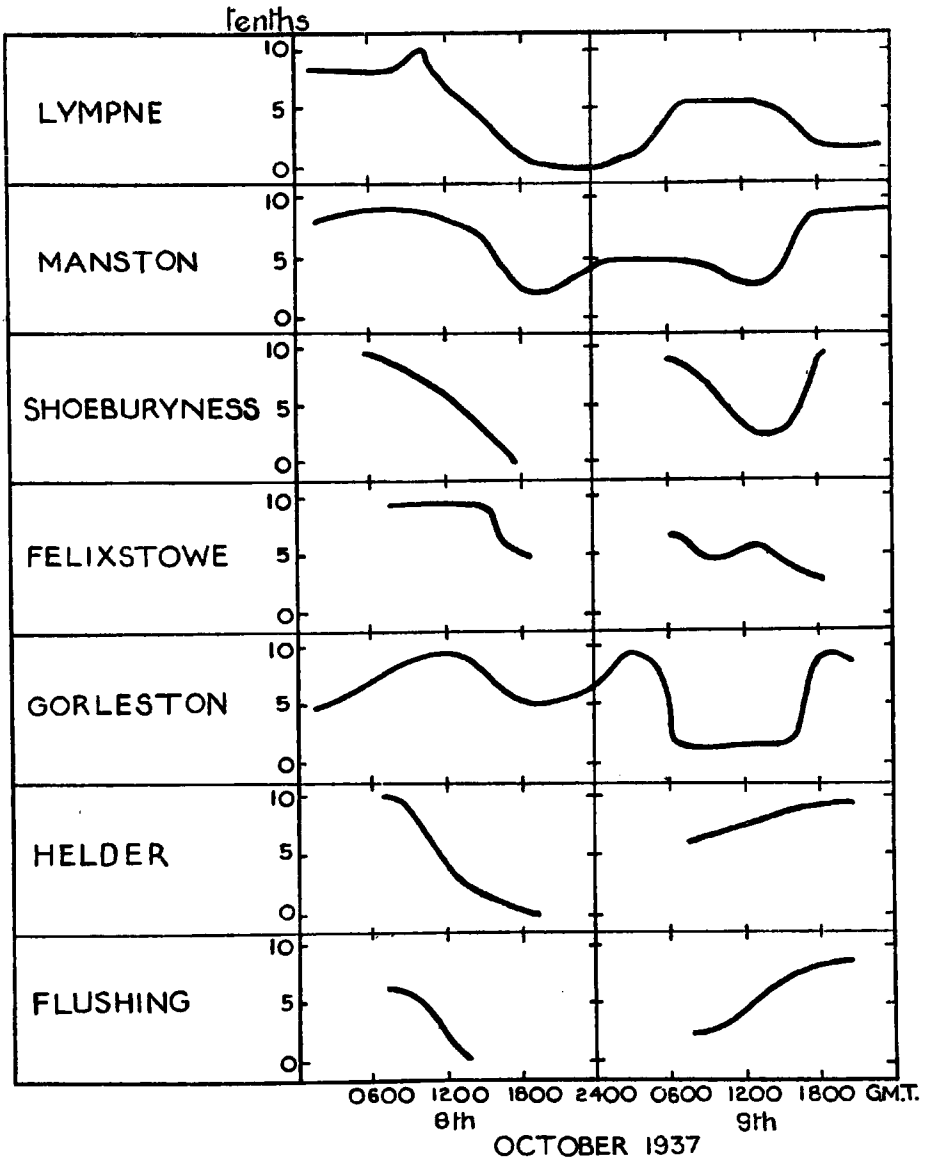

FIG. 3.—CLOUD VARIATION WITH NE. WINDS
Cloudiness given in tenths of sky covered with low cloud

Mr. Zobel points out that this layer of haze (more properly mist) which remains for some time after the cloud has cleared is as troublesome to pilots of aircraft as the cloud. Pilots' reports received at Bircham Newton show that the vertical visibility in this mist layer is often only a few hundred feet. The mist layer tends to become thicker before the cloud reappears.

The period April 29 to May 2, 1937 was one of continuous NE. winds on the east coast with very persistent stratus cloud. Fig. 1 shows the variations in the amount of this cloud at Lympne, Shoeburyness, Felixstowe, Gorleston and De Bilt (Holland). It will be observed that there were considerable

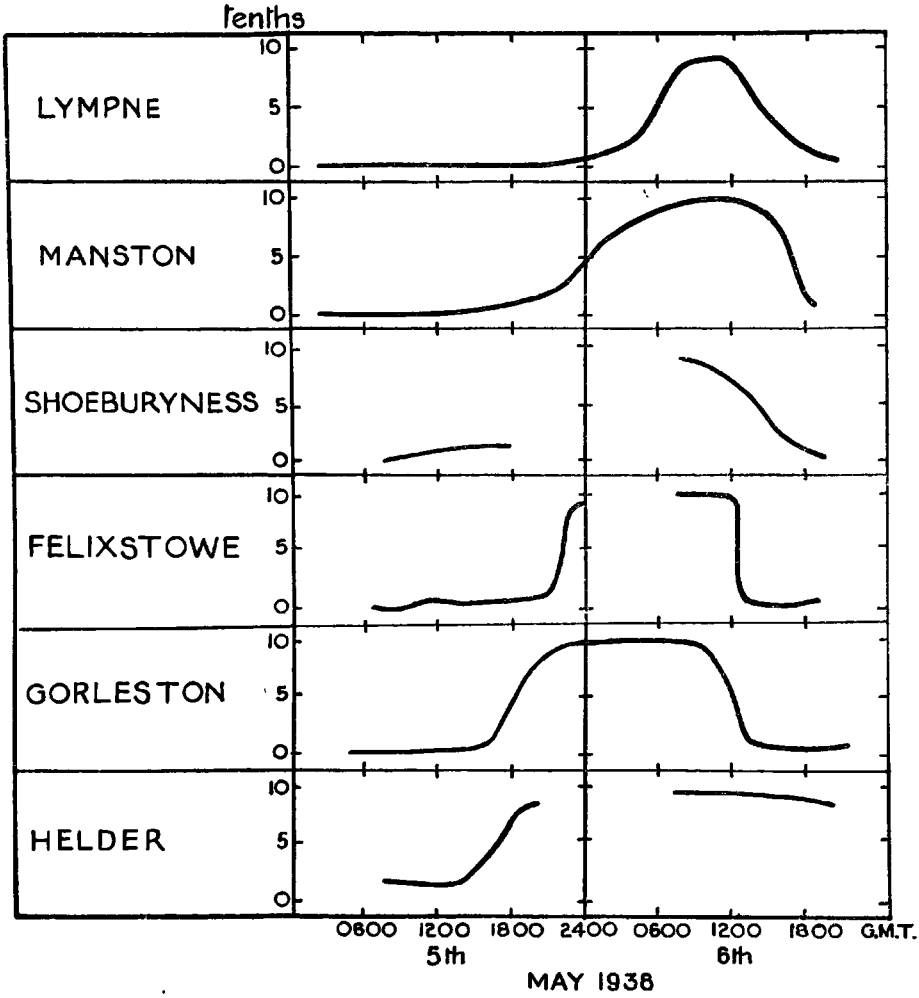

Fig. 4.—CLOUD VARIATION WITH NE. WINDS
Cloudiness given in tenths of sky covered with low cloud

differences from place to place. On April 30, for instance, the cloud cleared for a time in the afternoon at Felixstowe and half-cleared at Lympne, yet at Manston, Shoeburyness and Gorleston the sky was overcast all day. Owing to lack of observations at night at many stations, the complete variation throughout the period cannot be shown.

Figs. 2, 3 and 4 show the diurnal variation, and variation from place to place, of cloudiness during other periods of easterly wind over the North Sea. The observations from some Dutch stations are included for comparison with the British ones. The tendency of the cloud to clear by day and return at night is well shown in these diagrams.

Forecasting.—The problems which confront a forecaster at an east-coast station in connexion with North-Sea cloud are those of predicting whether or not cloud present in the early morning will clear during the day, and at what time; and, should it clear during the day, whether or not it will return at night.

If no changes in the synoptic situation are expected, it is found best to use the nearest morning upper air temperature and cloud observations. These give the height of the top of the cloud from which the rise of surface air temperature necessary to disperse the cloud can be found in the manner described on p. 2. The usefulness of this method can easily be shown with the aid of a few examples.

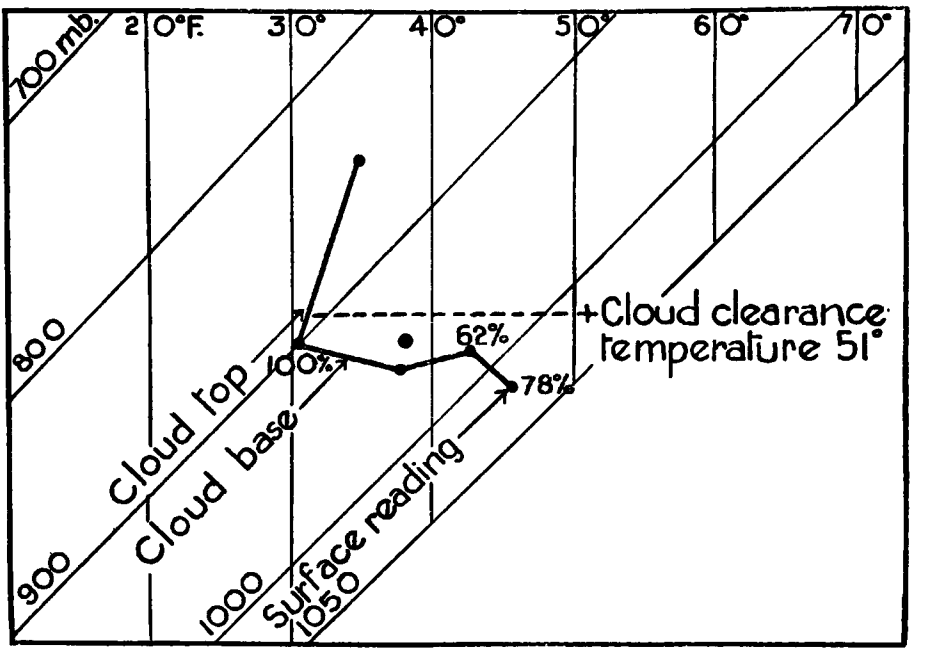

FIG. 5.—MILDENHALL, 0615, MAY 6, 1938

Fig. 5 is the tephigram drawn from Mildenhall upper air temperature readings made at 0615 G.M.T. on May 6, 1938. The cloud data reported with the temperatures are also shown. Using the method already described the cloud would be expected to clear when the ground-level temperature reached 51°F. Actually, at Felixstowe it had almost cleared when surface temperature had risen to 50°F. Fig. 6 is the tephigram for August 2, 1938 at 0600 G.M.T. The predicted value of surface air temperature for cloud clearance was 73°F. At Felixstowe the cloud cleared when temperature rose to 69°F. Finally, Fig. 7 is the tephigram for October 8, 1937, 0700 G.M.T. On this occasion the predicted value of surface air temperature for clearance was 61°F. At Felixstowe the surface air temperature rose to 59°F. Large holes formed in the cloud but it did not clear entirely. It is noteworthy that the cloud may clear for a value rather less than that predicted from the tephigram. This may be due to heating of the top of the cloud by sunshine. On August 2, 1938, for instance, the temperature of 69°F. which had been reached by the surface air when the cloud broke up is the value which the tephigram gives as the clearing value for a cloud with a top 300 ft. lower than that observed over Mildenhall in the morning. On the other hand it is quite possible that the cloud was less thick over Felixstowe than over Mildenhall.

It is necessary therefore to decide whether the temperature will rise to the required value. The method of finding the rise of temperature proposed by Krick[3] is to evaluate monthly mean values of the rise of temperature under

an overcast sky. This has been investigated for days of North-Sea cloud during the period 1931-38 at Felixstowe with results shown in Table V. It should be pointed out that the Stevenson screen, where temperature is measured, is 570 yd. from the nearest point of the beach. Days when the cloud cleared are given separately from those when it did not, but in all cases only the rise of temperature under a sky overcast or nearly so is given. The values are the differences between the temperature at the time stated at the head of each column and the temperature at 0700 G.M.T. The values are positive or zero except for values prefixed with a minus sign.

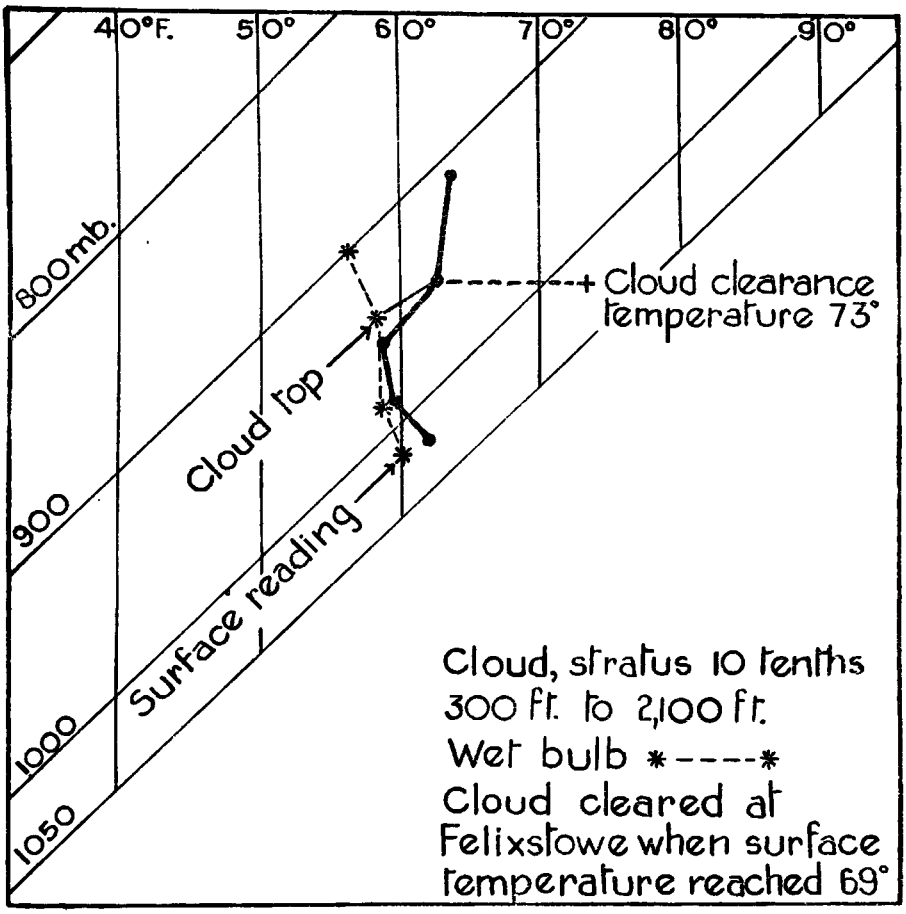

FIG. 6.—MILDENHALL, 0600, AUGUST 2, 1938

It will be noticed that the rise in temperature under the cloud was greater, on the average, on days when the cloud cleared than on days when it did not. The most obvious explanation of this is that the cloud was then less thick. Examination of the extreme cases shows that, except for the December day when temperature fell throughout the day, they all occurred on days when the early morning wind was light, force 3 or less. They are thus to be attributed to a pronounced night inversion near the ground.

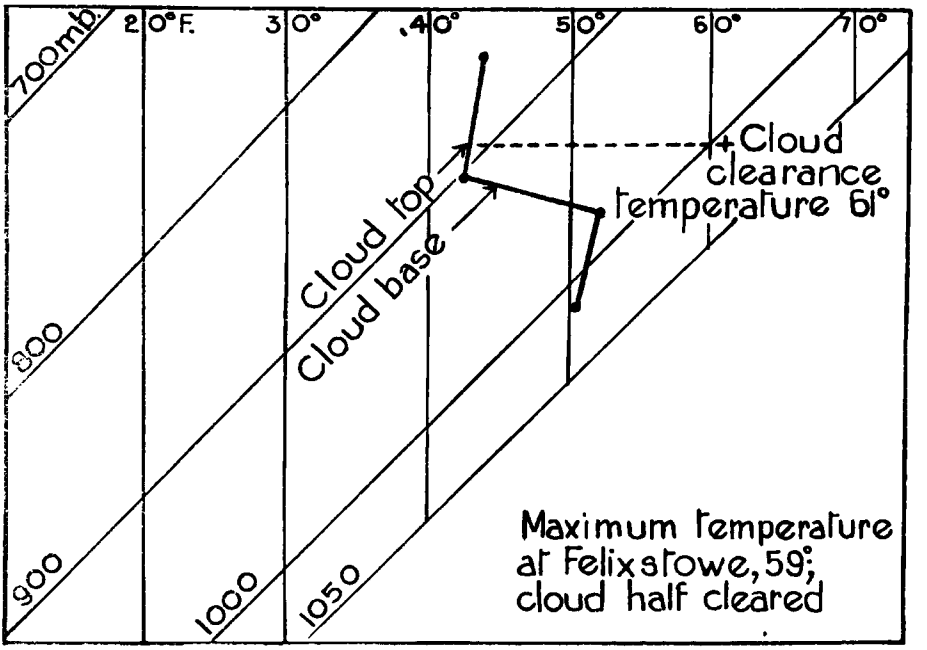

FIG. 7.—MILDENHALL, 0700, OCTOBER 8, 1937

TABLE V—AVERAGE VALUES OF TEMPERATURE AT TIMES STATED MINUS TEMPERATURE AT 0700 G.M.T., ON DAYS OF SKY OVERCAST WITH NORTH-SEA CLOUD

Period 1931-38

		0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	No. of cases
		degrees Fahrenheit										
Jan.	Subsequent clearance ..	0·3	0·3	0·7	1·7	..	..	..	..	..	..	3
	No clearance	0	0·6	0·6	1·3	1	1	1	1	1	0	10
Feb.	Subsequent clearance ..	1	1·7	2·7	4	5	5	5	..	..	..	3
	No clearance	0·3	1·2	2·3	2·5	3	3	3	2·8	2·5	2·2	19
Mar.	Subsequent clearance ..	1	1·5	2·5	3·3	3·5	4	4	..	..	..	3
	No clearance	0·5	1·5	2	2·3	2·3	2·3	2·3	2·2	1·5	1·3	10
Apr.	Subsequent clearance ..	1·7	3	4	5·7	..	..	..	..	..	..	4
	No clearance	0·5	2	2·5	2·7	3	2·9	2·9	4	2·7	3	11
May	Subsequent clearance ..	1	2	..	..	..	..	..	..	..	..	9
	No clearance	0·5	1·5	2	2·3	2·7	3	2·5	2·5	2	2	10
June	Subsequent clearance ..	1·7	2·5	2·5	3·5	3·4	..	..	..	..	..	6
	No clearance	1	1	2	2	3	3	3	3·5	3	2·5	6
July	Subsequent clearance ..	2	4	5	6	..	..	..	..	..	..	3
	No clearance	1	3	4·5	4·5	4·7	4·7	4·7	4	4	3·5	5
Aug.	Subsequent clearance ..	2	4·7	..	..	..	..	..	..	..	..	7
	No clearance	..	..	..	..	..	..	..	..	..	..	0
Sept.	Subsequent clearance ..	3	4	6	..	..	..	..	..	..	..	3
	No clearance	2	2	5	5	4·5	5	5	4	4	2·5	4
Oct.	Subsequent clearance ..	3	4	6	..	..	..	..	..	..	..	3
	No clearance	0·5	1	1·5	2·5	2·5	2·7	3	3	2·5	2·3	10
Nov.	Subsequent clearance ..	2	2	2·7	5	..	..	..	..	..	..	5
	No clearance	0·3	0·5	1	1·2	1·5	1·5	1·3	1·2	1	0·7	21
Dec.	Subsequent clearance ..	1	1	2	3	..	..	..	..	..	..	1
	No clearance	0	0·3	0	0	−0.5	−0·5	−0·5	−0·7	−0·7	−1	11

TABLE VI—EXTREME VALUES OF TEMPERATURE AT TIMES STATED MINUS TEMPERATURE AT 0700 G.M.T., ON DAYS OF SKY OVERCAST WITH NORTH-SEA CLOUD

Period 1931-38

	0800	0900	1000	1100	1200	1300	1400	1500	1600	1700	Remarks
	degrees Fahrenheit										
Jan.	0	1	1	2	3	4	5	5	5	5	No clearance
Feb.	1	3	9	10	11	9	9	9	9	9	No clearance
Mar.	4	8	10	11	12	12	10	9	9	8	No clearance
Apr.	1	8	6	7	7	8	8	8	8	7	No clearance
May	1	5	5	7	7	7	6	7	6	5	No clearance
June, July, Aug.	No case markedly different from average										
Sept.	8	8	9	10	..	..	..	..	..	..	Clearance
	3	6	8	8	7	7	7	7	7	6	No clearance
Oct.	0	0	1	5	5	5	8	7	7	3	No clearance
Nov.	3	3	5	5	5	5	5	5	5	4	No clearance
Dec.	1	1	2	2	2	3	3	3	3	1	No clearance
	0	0	−2	−2	−3	−4	−4	−4	−5	−5	No clearance

After sunrise the slight insolation, which penetrates even the thickest cloud, gradually weakens the ground inversion until it may be thin enough for turbulence suddenly to destroy it completely and so produce a rapid rise in temperature. The average values must, therefore, be used with caution on mornings of light wind.

The clearance of the cloud usually takes place by midday. If the sky is still overcast at 1400 G.M.T. there is very little prospect that it will become clear later in the afternoon.

Once steady NE. winds are established, the cloud is practically certain to return at night if it has cleared in the day. The return takes place when the temperature has fallen to, or rather below, the value it had when the cloud cleared, though data on this point are rather limited. There is a marked tendency for the first streaks of scud to appear during the period of an hour before to an hour after sunset. This is supported by some unpublished data of observations of the time of onset of North-Sea cloud in the evening by Crossley at Manston (near Ramsgate) in 1935. Forecasting the return of North-Sea cloud in the evening is thus a matter of deciding whether or not any change in the general meteorological situation is likely.

Summary.—The stratus cloud, which unassociated with fronts often occurs over the east coast of Great Britain with winds from the North Sea, depends mainly upon dynamical turbulence. Radiation may play some part, but a quantitative estimate of its effect is difficult to obtain. There is a marked diurnal variation in the amount of this cloud. Except in winter, it has a strong tendency to clear during the day. Tables are given showing the diurnal variation as observed at Felixstowe. A problem is presented by the fact that when the cloud clears over the coast the clearance generally extends well out to sea.

A method of forecasting the amount of the cloud, which was found serviceable at Felixstowe, is described.

ADDENDUM

In his papers [13], [14] (and in his section 2 of Lamb's paper[9]). Frost has applied Ertel's theory of constant wind shear in the lower levels and the assumption that the mixing length is proportional to a power of the height to the problem of the modification of air over the North Sea and successfully shown how to calculate the temperature and humidity structure at any level over the sea from a knowledge of the structure over the lee shore and the sea temperature.

BIBLIOGRAPHY

1. POULTER, R. M.; Cloud forecasting; the daily use of the tephigram. *Quart. J.R. met. Soc., London*, **64**, 1938, p. 277.
2. BRUNT, D.; Physical and dynamical meteorology. Cambridge, 1934.
3. KRICK, I. P.; Forecasting the dissipation of fog and stratus clouds. *J. aero. Sci., New York*, **4**, 1937, p. 366.
4. ROSSBY, C. G. and Montgomery, R. B.; The layer of frictional influence in wind and ocean currents. *Pap. phys. Oceanogr., Cambridge Mass.*, **3**, No. 3, 1935.
5. HEWSON, E. W.; The reflection, absorption, and transmission of solar radiation by fog and cloud. *Quart. J.R. met. Soc., London*, **69**, 1943, p. 47.
6. PEPPLER, W.; Lokale Stratusbildungen am Bodensee. *Beitr. Phys. frei. Atmos., Leipzig*, **13**, 1927, p. 128.
7. KÖPPEN, W.; Wie ist der tägliche Gang der Bewölkung auf dem Meere? *Ann. Hydrogr., Berlin*, **66**, 1938, p. 340.
8. WADSWORTH, J.; Studies of wind and cloud at Malta. *Geophys. Mem., London*, **4**, No. 37, 1928.
9. LAMB, H. H.; Haars or North Sea fogs on the coast of Great Britain. Meteorological Office, London, 2nd Edition, 1943.
10. SUTCLIFFE, R. C.; The sea breeze at Felixstowe, a statistical investigation of pilot-balloon ascents up to 5,500 feet. *Quart. J.R. met. Soc., London*, **63**, 1937, p. 137.
11. GOLDIE, A. H. R.; Wind records from the Bell Rock lighthouse. *Geophys. Mem., London*, **7**, No. 63, 1935.
12. SHAW, SIR NAPIER; Manual of meteorology, Vol. II, Comparative meteorology. Cambridge, 1928.
13. FROST, R.; Turbulence and diffusion in the lower atmosphere. *Proc. roy. Soc., London*, A, **186**, 1946, p. 20.
14. FROST, R.; A note on polar air-mass modification. *Proc. roy. Soc., London*, A **198**, 1949, p. 27.

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